A RATIONALE FOR THE

SUSPENDED SOLIDS STANDARDS

FOR YUKON STREAMS

SUBJECT TO PLACER MINING

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A RATIONALE FOR STANDARDS RELATING TO THE DISCHARGE OF SEDIMENTS INTO YUKON STREAMS FROM PLACER MINES

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SUMMARY

Sediment is a broad spectrum pollutant that can degrade water quality and have severe negative impacts on aquatic habitat as well as cause damage to fish and associated aquatic populations. Natural levels of sediment can be limiting to the production in many streams and any significant increase in sediment levels over natural levels in a stream can cause much more significant decreases in aquatic life.

Guidelines for an administrative/regulatory framework to manage placer mining have been proposed. The basis of the approach for the aquatic environment is to identify resource sensitivities based on their biological importance. Five classifications (ie. A, B, C, D, and X) have been proposed based on biological sensitivities and past mining activity in each waterbody. In acknowledgement of these biological sensivities, the rather complex ecological inter-relationships between sediment and stream life and mining history, a sediment discharge maximum standard is proposed for each stream classification.

Sediment discharge standards to the waters of the above classifications are proposed to be 0 mg/l for all A waterbodies, 100 mg/l for all B and C streams, 100 or 1000 mg/l for all D streams and 100 or 1000 mg/l for X streams. These standards are upper limits of acceptable levels and are defined for effluents from the operation as opposed to receiving water standards. The standards reflect the biological sensitivity of each stream and are a recognition of existing practice. With time, it is possible that some D and X classifications and associated effluent standards may be upgraded.

1.0 INTRODUCTION

Sediments are fine particles of soil or rock that can be carried or deposited into natural waterways by a variety of processes. Usually these sediments consist of particles less than 3 mm in diameter and can be carried by flowing water. It is for this reason that they are also referred to as suspended solids and are measured as non-filterable residue.

Such sediments or suspended solids have always been of extreme importance in the development of streams and the aquatic life found in those streams. Large amounts of sediments are carried by natural processes into many of our streams. In Western North America this process is more noticeable in watersheds that are geologically young or active. In more stabilized watersheds, streams are relatively sediment free during all or at least a significant portion of the year. Where this is not the case, the productivity of the aquatic life in those streams has been severely limited. This is especially the case where our salmonid streams are naturally characterized by a clean water regime and a coarse stream substrate.

Where these streams have a relatively stable sediment regime, one will find species of aquatic life which have been selected by natural processes and are therefore tolerant of that sediment regime. Where the stable regime is exceeded in a significant manner, the tolerance of the species present will also be exceeded and fish productivity is usually significantly impaired. Species can of course tolerate or compensate for variations in sediment levels from stream to stream or from year to year but the species cannot physiologically nor morphologically adapt to survive significant increases over the natural regime which has been established over thousands of years of hydrogeologic evolution.

Other than natural catostrophic events such as slides, the activities of man have done most to significantly alter or increase sediment levels over the natural stable regime in our streams. It is this

change or increase over the natural regime or background levels which can severely limit the natural production in any stream. Since sediment can have a multitude of deleterious effects on our streams, the precise role sediment plays in reducing aquatic production is difficult to document. This fact and the knowledge that sediment is a naturally occurring material has all too often caused individuals to overlook or underestimate the impact of this subtle pollutant.

Published accounts of the deterimental effects of sediment in British Columbia began approximately 70 years ago (Harrison 1916). Sediment has been acknowledged as a major pollution problem and in a review paper written over 20 years ago, Cordone and Kelley (1961) discussed the findings of over 100 papers on the subject.

Current operational methods used to placer mine gold in the Yukon often result in significant sediment inputs into local streams. The effects of sediment on fish from placer mines were first documented over 40 years ago (Smith, 1940). Research and experience during the past two decades have strongly supported earlier findings. Although most studies were conducted in areas in Western North America outside of the Yukon, the ecological and associated physical principles involved are applicable to Yukon streams.

In the Yukon, many placer mines represent a conflict with the maintanance of acceptable water quality in many streams. Suspended solids entering a stream is usually finer than sand and can be organic or inorganic. Generally placer mining activity occurs from about mid May to early October of each year. Most organic solids usually enter the stream near the beginning of the season whereas a greater percentage of inorganic solids is released during the main part of the season as sluicing and stream channel diversion occur to facilitate the recovery of gold. In that most of the organic sediment will be stockpiled for reclamation purposes and since the inorganic sediment is of much greater volume, this paper will limit discussion to inorganic sediments.

Inorganic sediment, once in a stream, may be transported in the water column as suspended solids or may settle and become part of the

substrate of the stream. Thus the effect of sediment on an aquatic ecosystem reflect these two modes of action. The effects that suspended solids will have on the stream generally relates to its effects on light transmission through the water column (turbidity) or its direct effects on organisms either by an abrasive or clogging mechanism.

Sediment which settles or is filtered out of the water column by passing through the stream bottom has the effect of reducing the average particle size of the substrate thus reducing the amount and size of interstitial space available in the substrate for organism living space and normal sub-gravel water movement.

The above effects may be short term or may last several months to several years depending on the type, quantity and duration of sediment discharge. Annual cycles of flushing will resuspend the fine sediments and move them downstream, however, the effects of large sediment and the ability of aquatic populations to recover may even take longer. Generally, the greater the amount of sediment released and the longer the duration of release, the greater will be the detrimental effects on the habitat and associated aquatic populations.

2.0 EFFECTS OF SEDIMENT ON PRIMARY PRODUCERS

Aquatic plant communities in the fast-flowing, cool water streams of the Yukon are primarily composed of attached algae. These in-stream photosynthetic organisms are an important part of the food chain base and are thus important to the entire aquatic community. Three ways have been postulated (Hollis et al., 1964; Pickral, 1981; Cordone and Kelley, 1961; Griffiths and Walton, 1978; Sorenson et al., 1977) whereby sediment may affect aquatic plants, namely: 1) reduction in light due to absorption by sediment in the water column or covering the surface of plants, 2) abrasive action of sediment on aquatic plants causing erosion and damage to the plants; and 3) blanketing of stable rock substrates necessary for optimal algal growth with less stable fine material. The independent effects of these three factors on the aquatic plants have proven difficult to assess because of their concurrent interaction. Hollis et al., (1964) indicated that one percent of incident light could penetrate 9.7 m through water of 5 mg/l suspended solids but could pass only 0.8 m through water of 115 mg/l. About one percent (0.4% to 1.5%) of incident radiation is usually considered to be the compensation point where photosynthesis and respiration of algae balance and thus no growth would occur (Ruttner, 1963). Each of the reviews by Hollis et al. (1964), Griffiths and Walton (1978), Sorensen et al. (1977), Cordone and Kelley (1961) and Pickral (1981) indicate that reduction in plant growth and perhaps changes in community structure are to be expected in waters where sedimentation is occuring. Quantification of the changes in production were limited but according to Hollis et al. (1964) algal productivity in turbid water may be expected to be reduced from 19% to 90% below that occurring in clear water.

It should be noted that there is a distinction between the term turbidity and suspended solids (nonfilterable residue). Turbidity pertains to the amount of light that is transmitted through a sample of water, whereas suspended solids refers to the mass of solids in a sample

of water. In a series of water samples a correlation may exist between the two parameters providing soil characteristics remain identical. However, an inverse relationship can occur between turbidity and suspended solids should different sizes of particles occur in each sample of a test series (e.g. 100 mg/l of clay would shown higher turbidity than 1000 mg/l of sand). Because of the different particle size characteristics of different soil types, a good correlation of suspended solids and turbidity would not be expected between different soil types. However, for any uniform soil type, particularly at a specific location, a positive correlation should exist between turbidity and suspended solids.

3.0 EFFECTS OF SEDIMENT ON STREAM INVERTEBRATES

Effects of increased inorganic solids loadings to streams have also been demonstrated on the benthic invertebrate component of aquatic stream communities. Most studies conducted on this component of the community have taken place as cause and effect studies thus definitive statements with regard to the probable effect cannot be made due to a multiple of causes. However, it is thought that reduction in benthic invertebrates in affected streams have been the direct result of increased suspended solids and sedimentation of the substrate (Chisholm and Downs, 1978; Ciborowki et al., 1977; Luedtke and Brusven, 1976; MacFarlane, 1978; Rosenberg and Weins, 1978; Sorensen et al., 1977; Griffiths and Walton, 1978; Cordone and Kelley, 1961; Pickral, 1981; Gammon, 1970). Indirect effects have also been associated with reduction of food resource through decreased algae production (Cordone and Kelley, 1961; Griffiths and Walton, 1978) and by decrease of the ratio of organic to inorganic solids transported in the stream or on the stream bottom (MacFarlane, 1978; Naiman and Sedell, 1979).

Increased suspended solids have the direct effect of causing increased insect drift (Ciborowski et al., 1977; Rosenberg and Wiens, 1978; Gammon, 1970). Gammon (1970) was able to show that insect drift was increased by 25% with an increase of 40 mg/l suspended solids and by 90% with an increase of 80 mg/l of suspended sediments above normal. As most drifting aquatic insects are felt to originate from the stream bottom within 50 m of the point of collection (Elliott, 1967) the continued above normal input of sediment and resultant increased drift rate of invertebrate has implications for depletion of benthic invertebrates in the affected area. Actual change in benthic invertebrates density as a result of increased drift from sediment additions causing suspended solids levels of 7.4 to 7.7 mg/l has not been shown during short-term experiments (Rosenberg and Wiens, 1978) although reduction of benthic invertebrate population numbers has been demonstrated as discussed later.

High inorganic suspended solids will also act directly on filter feeding organisms by clogging their feeding apparatus so that they cannot feed (Gammon, 1970). Suspended solids may also abrade and damage gills of some invertebrates (Griffiths and Walton, 1978). However, sediment blanketing of the substrate probably has the most adverse direct effect on benthic invertebrates. It has been shown that coarse stream substrates consisting of cobbles and boulders are more productive than fine particle substrates composed of sand and silts (Cordone and Kelley, 1961; Pickral, 1981; Sorensen et al., 1977). Sediment effects studies have found reductions in invertebrate standing crop ranging from 40% to 90% (Pickral, 1980; Cordone and Kelley, 1961; Scullion and Edwards, 1980) and reductions in diversity of the benthic community (Gammon, 1970; Pickral, 1981; MacFarlane, 1978; Chisholm and Downs, 1978; Scullion and Edwards, 1980). The reductions in standing crop and changes in community structure have been associated with the reduction of the heterogeneity of the habitat by the filling of interstitial spaces with fine particle materials (Cordone and Kelley, 1961; Gammon, 1970). However, the habitat may be restored in a one or two year period provided that sedimentation is not extreme and the source of inorganic sediments is removed (Cordone and Kelley, 1961; Chisholm and Downs, 1978; Pickral, 1981; Griffiths and Walton, 1978; Sorensen et al., 1977). Most of the studies mentioned did not consider the effects of long term sediment sources and subsequent recovery rate of streams. However, experience has shown that continuous sedimentation may cause significant infilling and compaction of gravel substrates which are highly resistant to natural rehabilitation.

4.0 EFFECTS OF SEDIMENT ON FISH

Considerably more work has been conducted to determine the effect of sediment on fish than any other component of the aquatic community. Most studies have concentrated on the effect of accumulated sediment in the substrate on the survival of eggs and emergence of salmonid fish. However, in recent years more effort has been directed toward evaluating the effects of suspended solids on fish populations and behavior. The effects, as indicated above, can be broadly separated by whether the sediment is suspended or deposited on or in the substrate and as direct or indirect. Indirect effects are primarily related to habitat alienation or loss of food resources through sedimentation of the substrate, whereas direct effects related to the ability of fish to carry out day to day activities or affect survival of different life stages, such as eggs and alevins.

Salmonid fish depend largely on aquatic invertebrates for their food. The reduction of this resource as discussed in the previous section will have a significant effect on the ability of the stream to support fish. Habitat alienation has not been directly studied as this factor is more subtle and hence not easily separated from other more direct effects.

Numerous studies have been conducted to determine the effects of deposited sediment and different substrate compositions on water movement through the substrate and subsequent survival of salmonid eggs and emergence of juveniles (Phillips et al., 1975; Shelton and Pollock, 1966; Cobble, 1961; Hausle and Cobble, 1976; Cederholm et al., 1980; McNeil, 1966; Rukhlov, 1969; McNeil and Ahnell, 1964; Cederholm and Salo, 1979; Witzel and MacCrimmon, 1981; Vaux, 1968; Wickett, 1960; Peters, 1962; Shaw and Maga, 1943; Hall and Lantz, 1969; Cooper, 1965; Phillips, 1970). The findings of these studies were in essence that introduction of fine particles to the substrate reduce the movement of oxygenated water through the gravel and thus reduce survival of eggs and inhibit emergence of fry. Cooper (1965) showed that stream water continuously passes in and out of

the streambed indicating that even the very finest of particles would eventually be filtered from the stream. McNeil (1964) and Hall and Lantz (1969) found that fines up to 3 mm in size in the streambed should not exceed 10% to 15% of the streambed composition for successful spawning of salmon. Witzel and McCrimmon (1981) found that survival of rainbow trout eggs in ungranular gravels increased with size to 26.5 mm, and that the largest incremental change occurred between particle sizes of 2 and 8 mm. Scullion and Edwards (1980a) found that salmonid eggs exposed to suspended and ferruginous solids experience greater than 80% mortality. Auld and Schubel (1978) found that the eggs of the American shad, a broadcast spawner, hatched at concentrations of suspended solids of 1000 mg/l but that larvae exposed to concentrations greater than 100 mg/l showed significantly reduced survival. Fry of nest making salmonids can be entrapped after hatching when sand or smaller materials are incorporated in the substrate; when fines, less than 3 mm, reached 70% emergence of salmon fry was reduced to 8% (Phillips et al., 1975). Cederholm and Salo (1979) found that increases in sediments less than 0.850 mm, of 2.33% (8.36% to 10.69%) and 0.76% (8.36% to 9.12%) caused reduction in salmonid egg to fry survival of 11.6% and 3.8% respectively, thus indicating the effect that relatively minor increases in fine material may have a marked effect on salmonid reproductive success. Langer (1980) showed that in the Coquitlam River, a British Columbia stream, that a 12 percent increase in suspended solids accounted for a 55 percent decrease in salmon egg survival.

All of the above studies demonstrate the significant effect that small increases in sediment can have on salmon egg and fry survival. The mode of action on eggs and fry in the gravel is through the filling of interstitial spaces. This causes a reduction in oxygenated water movement through the gravel and causes a subsequent lowering of oxygen levels within the gravel (Wickett, 1958) and severely affects egg survival (Wickett, 1954). The other effect of the filling of interstitial spaces is to inhibit the movement of fry from the streambed into the stream. Experiments by Hall and Lantz (1969) showed that 1 to 3 mm sand in

concentrations of 20 to 50 percent of the substrate reduced emergence by 40 to 80 percent. These two effects are combined in field studies where the effect is additive on survival to emergence. This combined effect is accentuated even more by finer particles (less than 0.83 mm) as demonstrated by Hall and Lantz (1969).

Suspended sediments can have a variety of effects on fish including abrasion and disease susceptibility, changes in ventilation rates, feeding behavior, avoidance, growth and acute toxicity. Herbert and Merkens (1961) and Noggle (1978) have shown that acute lethal levels of suspended solids to salmonid fish are high and, in fact, are probably higher than would be normally expected to occur for extended periods in nature (EIFAC, 1965). However, Herbert and Merkens (1961) found that gill tissue was damaged by concentrations of solids as low as 270 mg/l and that the incidence of fin rot was increased with exposure to suspended solids. Whitman et al., (1982) showed that suspended solids of 650 mg/l, (i.e. volcanic ash), inhibited homing of adult salmon, whereas Noggle (1978) found that juvenile salmonids exposed to suspended sediment concentrations of 1,000 to 4,000 mg/l did not avoid those levels but those exposed to 4,000 to 12,000 mg/l did show an avoidance response. EIFAC (1965) reported chinook salmon selected clear water locations or tributaries for spawning. In general, concentrations of suspended solids which cause acute effects to juvenile and adult fish are much higher than those known to cause severe effects on stream communities and thus are of little value in establishing the expected effects on stream communities.

Several studies have been carried out which indicate that salmonids exposed to either suspended solids or solids which have settled to the stream bottom have experienced lowered growth rates (Crouse et al., 1981; Sigler, 1981; Herbert and Merkens, 1961). The study by Sigler (1981) also indicated that the fish exposed to suspended solids did not compete well with fish from clear water. Scullion and Edwards (1980a) found that brown trout populations were reduced and fish showed low condition factors when exposed to 100 mg/l average suspended solids.

Other studies have also been carried out which allude to the capability of fish to inhabit turbid waters. Gardner (1981) has shown that bluegill feeding rates were reduced by turbidities as low as 60 NTU. Noggle (1978) found that suspended sediment concentrations of 100 mg/l reduced feeding of coho by about 45%, that at 250 mg/l feeding was reduced by 90% and above 300 mg/l feeding ceased altogether. Phillips (1970) indicated that fishing success for salmonids declines when turbidity exceeds 25 ppm. EIFAC (1965) reports that cutthroat trout exposed to 35 mg/l of suspended solids stopped feeding and sought cover. Horkel and Pearson (1976) suggested that green sunfish in highly turbid water increased ventilation rates to compensate for reduced respiratory efficiency thus maintaining a constant oxygen uptake. These studies indicate the fish in turbid waters may require the expenditure of more energy while the capability of energy recovery through food intake is reduced.

In summary, sediment introduction to a stream, whether it is short or long-term, has a deleterious effect on the aquatic community. The duration of such effects, provided that sediment input ceases, depends on the duration and severity of inputs as well as a variety of other factors but would extend from several months to several years. Sediment, once in a stream, influences the biota whether it is in suspension or on the stream bottom. When in suspension it reduces light penetration and acts as an abrasive. Sediment in and on the substrate affects algae, invertebrates and fish by filling the interstitial spaces and coating the gravel surface. The resulting substrate is less heterogeneous, is less stable, is less permeable to water movement and exhibits greater compaction. These factors taken altogether or individually are known to reduce the productive capacity of a stream and to reduce the biotic diversity through habitat alienation. The greatest danger from sediment in streams is not the acute effects on the biota but is instead the more subtle and deleterious chronic effects which interfere with an organisms capability to survive.

Smith in 1940 recognized the effects of siltation, although it is likely that his understanding of the mechanisms were more imperfect than present day. The conclusion remains as he stated it: "However, it should be known and recognized that continued silting of streams is detrimental to game fish, or at least to their reproduction and food supply, and this undesirable condition should be balanced against the public benefits resulting from hydraulic mining."

5.0 DISCHARGE STANDARDS

Guidelines for an administrative/regulatory framework to manage placer mining has been proposed. The basis of the approach for the aquatic environment is to identify resource sensitivities based on their biological importance. Five stream classifications have been suggested along with sensitivity matrices for biological evaluation of each waterbody.

The classifications are: "A" indicating waterbodies which have high biological importance, "B" and "C" for waterbodies which have moderate biological importance, "D" for waterbodies of low biological importance and "X" for previously designated placer mining areas. "A" classifications are associated only with high importance relative to Schedule I fish (eg. salmon, trout or char) spawning area. "B" classifications would serve as rearing areas for Schedule I fish. "C" classifications are good habitat areas for Schedule II fish (eg. grayling, whitefish or burbot). "D" classifications would exhibit low or no use by any of the above fish or be used only as migration corridors.

In recognition of these sensitivity based classifications, the fact that sediment is a broad spectrum pollutant, and of past mining activities, a maximum sediment discharge standard is proposed for each stream classification.

5.1 Class A Streams

A number of authorities in North America and elsewhere have indicated that healthy fish populations can be maintained when effluent discharges to streams were at or below 25 mg/l suspended solids (Thurston et al., 1979; EIFAC, 1965: U.S. EPA, 1973). However, realizing that it is not often realistic to expect sediment containing works to consistantly produce an effluent 25 mg/l or better of suspended solids at most placer mines, the only alternative is a closed system with no discharge in such sensitive waterways. The studies reviewed in the introduction indicated

the severe effects that could be expected from relatively low level introductions of sediment to biologically sensitive streams.

Cederholm and Salo (1979), Hall and Lantz (1969), Langer (1980) and several others have demonstrated the significant effect that low levels of sediment could have on egg to fry survival of salmon. This is particularly crucial when it is considered that under good natural conditions only 10 to 30 percent of the eggs deposited by trout and salmon survive to emergence (Phillips, 1970). Small additions of sediment will greatly reduce this survival rate (Langer, 1980). Further decreases in survival could severely affect the viability of a salmonid population.

Considering the above it is necessary to recommended no sediment discharge to class "A" waters to ensure adequate protection for these highly sensitive and important waters.

5.2 Class B and C Streams

Streams or parts of streams that are used by Schedule I fish for rearing or that provide good habitat for Schedule II fish can maintain viable fish populations with sediment release regimes of up to 100 mg/l. Viable populations can often be found where sediment concentrations reach 100 mg/l. To maintain a viable population, the sediment regime must allow for food production and satisfy rearing habitat requirements for Schedule I fish species or rearing and spawning habitat requirements for Schedule II fish species and not have a direct impact on the fish.

The egg stage of salmon, trout and char is the most sensitive period in their life cycle and is more sensitive to sedimentation than other segments of the aquatic community and could not withstand the higher effluent standards. While the remainder of the community will be affected by suspended sediment loads of 100 mg/l, viable stream communities can be maintained. The 100 mg/l suspended sediment would cause reduction in benthic invertebrate populations but this food resource would not be fully depleted (Rosenberg and Wiens, 1975; Gammon, 1970; MacFarlane, 1978). Scullion and Edwards (1980a) found that a brown trout population was

maintained at decreased levels in 100 mg/l average suspended solids. Noggle (1978) and EIFAC (1965) indicate that suspended solids of 100 mg/l should not block migration of fish.

It is sometimes felt that Schedule II fish such as Arctic grayling being broadcast spawners may have less susceptible egg stages to sediment than other fish. However, grayling are known to be clean water fish and additional research may indicate a higher sensitivity to sediment. In fact, several studies indicate greater sensitivity to sediment than previously thought. Bishop (1971) indicated that grayling have eggs which are very adhesive until they become water hardened. Kratt and Smith (1977) have reported that grayling has a post-hatching sub-gravel stage in development. Eriksen (1975) stated that one of the reasons for disappearance of the southern grayling from some of its range was due to sedimentation of spawning beds. Eggs of American Shad, also a broadcast spawner but not a salmonid, survived 1000 mg/l suspended solids but larvae suffered significant mortality above 100 mg/l (Auld and Schubel, 1978). These studies indicate a certain requirement for clean water and clean substrates that has not been appreciated to-date.

Nevertheless, it is currently felt that the 100 mg/l standard could maintain a relatively clean benthic surface to satisfy broadcast spawner requirements although additional studies may alter this perception.

In summary, the 100 mg/l standard should allow maintenance of residual salmonid populations as a basis for later stream rehabilitation.

5.3 Class D Streams

It has been well documented that although 1000 mg/l concentrations of suspended solids may not cause direct salmonid fish mortality, it will seriously impact the aquatic environment. Benthic invertebrate populations would be significantly affected by the release of this high concentration of suspended solids (Gammon, 1970; Sorenson et al., 1977). Feeding behaviour of fish would be affected (EIFAC, 1965; Noggle, 1978).

Resistence of fish to disease would be lowered (EIFAC, 1965). Fish populations would be significantly reduced or depleted (Sorensen et al., 1971). However, fish migration through areas of high suspended solids should not be blocked (EIFAC, 1965; Noggle, 1978).

Considering that D class waterbodies are characterized by having low capability for fish usage the damage inflicted by high sediment loadings would be minimized. However, where a D class stream enters an A, B or C class stream consideration of downstream effects on the aquatic environment must take place. Therefore where a D class stream enters an A, B or C stream, the standard that applies to discharges into that D stream must be a maximum of 100 mg/l of sediment. Where the D stream is a tributary of a major D stream (i.e. a major migratory route), then the standard of 1000 mg/l will apply.

5.4 Class X Stream

In that past designated placer mining streams have a reduced biological capacity due to past mining activities a maximum sediment discharge standard of 1000 mg/l will prevent significant additional degradation of streambeds. Where an X class stream flows into a more sensitive Class A, B, C or non-major D stream then the standard of 100 mg/l will apply.

In order to rehabilitate X streams, a discharge standard of 1000 mg/l is excessive and will have to be lowered to a level consistant with the protection of viable aquatic populations in other stream classifications.

6.0 DISCUSSION AND CONCLUSIONS

Sediment in a stream can be considered as a very broad-spectrum pollutant affecting all life forms from primary producers to adult fish. The overall impact on the aquatic community is as complex as the inter-relationship between the various organisms in the stream. The impact of a sediment release on stream production will depend on the organisms present, streambed composition, the season, stream flow, stream velocity, background sediment levels, the volume of the release, the duration of the release and the composition of the sediment. The above parameters dictate only the degree to which sediment will decrease production or harm stream life. A sediment release will always have some harmful effect regardless of the status of the above parameters.

The obvious effects of sediment on fish production will be most noticeable on certain stages of the life cycles. This will, of course, vary from species to species. Probably sediment causes the greatest reduction in fish production by causing mortality in the egg and alevin stages of development and in the degradation of their rearing habitat.

One cannot simply look at the obvious sediment effects on fish to gauge the damage sediment can have on a stream. Although sediment affects all stream life, these effects are not exerted equally on primary producers, invertebrates and fish. These life forms are linked together by food chains so any deleterious effect on algae will affect aquatic invertebrates and fish that depend on energy produced in the stream. For instance, it is of minor value to be concerned about the level at which stream sediments will clog the gills of fish or reduce their hiding areas because in most cases the entire food chain complex upon which these fish must depend, would have been destroyed well before the fish was directly harmed (Langer, 1980). If stream life is to be adequately protected from abnormal sediment levels, we must measure and be concerned about the more subtle effects of sediments. Cordone and Kelley (1961) most aptly describe

this concern: "short-term discharges of sediment may do little visible damage to fishes, bottom fauna, or fishes' eggs, but may interrupt the entire biological complex through effects on algae." In addition, it must be noted that the greater the sediment release volume and the longer its duration, the greater will be its impact on all life and production in the stream.

The above proposed sediment discharge standards for the various stream classifications are to be viewed as maximum sediment discharge standards as measured over background levels found in the stream upstream of mining activities. Certain of these standards will not totally protect aquatic life, however, when upgraded over the next several years, a level of protection will be offered which is comparable to that found in British Columbia, and other parts of Canada and North America. These standards will then insure that viable aquatic populations are maintained in most normal situations.

The standards proposed are discharge standards and not receiving water quality objectives. In that placer mines use large volumes of water, it is possible that in many streams that stream sediment levels downstream of an effluent discharge(s) will approach the effluent standard. Specifically, stream sediment levels may become elevated 100-1000 mg/l over background levels in worst possible scenario. Where this occurs, these levels may have to be reduced with time. Fortunately, in many streams, clean water dilution wil help mitigate these sediment loadings to more acceptable levels.

The proposed standards are seen as a minimum requirement should the renewable aquatic resources of the Yukon be protected to any reasonable degree.

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POOR

QUALITY

ORIGINAL